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AN INTEGRAL ROAD ACCESSIBILITY AS A CRITERION FOR ASSESSING THE QUALITY AND CONDITION OF A ROAD NETWORK

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ABSTRACT

The paper investigates integral road accessibility method for evaluation road network quality and condition. An Integrated Road Accessibility (IRA) - measured in travel time (hours) and shows the availability from one node to the other node in the territory (district, region, state, set of states) taking into account the number, density and weight of the population, location of the node, density of the road network, state of the traffic flow and roads, as well as traffic safety. Proposed mathematical method serves to show the level of IRA and each level determines the quality of the road network and traffic conditions.

KEYWORDS: Integrated Road Accessibility, Traffic Quality & Road Condition

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Original Article

INTRODUCTION

There are about in total 3 million vehicles (private and public) registered in Uzbekistan. Road density is 411.3 km per 1000 km^2. But it varies across regions from ranging from 67.6 to 2982.1 km per 1000 km^2. The percentage of roads with pavement (asphalt or concrete) is also varying from 13 to 55%.

To assess the quality of the road network and traffic conditions, a fundamentally new approach was proposed [1, 6, 7, 8] - An Integrated Road Accessibility (IRA). IRA - measured in travel time (hours) and shows the availability from one node to the other node in the territory (district, region, state, set of states) taking into account the number, density and weight of the population, location of the node, density of the road network, state of the traffic flow and roads, as well as traffic safety. IRA can serve as an indicator of the reliability of the road network. In order to create a certain level of road accessibility, it is necessary to identify territories that do not provide its minimum guaranteed level.

IRA is an analogue of the indicator of the reliability of the road network. At the same time, such a road network is considered reliable, which allows you to reach any point from any other in a certain standard time. In order to create a certain level of transport accessibility, it is necessary to identify territories that do not provide its minimum guaranteed level.

IRA as a tool for solving the problems of transport security was proposed in V.N. Bugromenko [10, 11, 13, 15] and other works [9, 12, 14]. In the author’s works [1, 3, 6, 7, 8], IRA was proposed as a criterion for assessing the quality of the road network and the traffic conditions. The author offers the following theoretical approach to the definition and evaluation of IRA in his research. Based on the previously proposed methodology for determining transport accessibility [1], we determine the integrated transport accessibility.

Defining Integral Accessibility

Accessibility of the node for some territory.

By the availability of Di of the node for a certain territory, we mean the expression

$$Di = \iint_{Д} P_i (x, y)\, q(x, y)\, dx\, dy \quad (1)$$

where - q(x, y) – density of the weight function of a given territory; D – area the integrated territory which can be represented as an area on the plane.

We can select the plane of the weight function so that

$$\iint_{Д} q(x, y)\, dx\, dy = 1 \quad (2)$$

If the density of the weight function q!(x, y) such that

$$\iint_{Д} q^{/}(x, y)\, dx\, dy = Q \quad (3)$$

then choose relatively

$$q(x, y) = \frac{1}{Q} q^{/}(x, y) \quad (4)$$

Wherein q(x, y) satisfies the expression (2).

In expression (1) P_i (x, y) – an indicator of the accessibility of this item for a point in the territory with x, y coordinates.

Accessibility D^{i} for a given node of some territory is expressed

$$D^{i} = \iint_{\overline{Д}} \overline{P_i} (x, y)\, \overline{q} (x, y)\, dx\, dy \quad (5)$$

where $\overline{Д}$ - given territory.

$\overline{q}$ (x, y) – the density of the weight function of the territory chosen in such a way that

$$\iint_{\overline{Д}} \overline{q} (x, y)\, dx\, dy = 1 \quad (6)$$

$\overline{P_i}$ (x, y) – accessibility for a given node of a point of territory with coordinates x, y.

Accessibility of the node with coordinates x!, y! for a certain territory defined as follows:

$$D(x^!, y^!) = \iint\limits_{Д} P(x^!, y^!, x, y)\, q(x, y)\, dx\, dy \tag{7}$$

Here P(x!, y!, x, y) – accessibility indicator from a node with x, y coordinates, to a node with x!, y! coordinates.

Accessibility of the given node with coordinates x!, y! for certain territory expressed as follows:

$$D(x^!, y^!) = \iint\limits_{Д} P(x, y, x^!, y^!)\, \bar{q}(x, y)\, dx\, dy \tag{8}$$

where $P(x, y, x^!, y^!)$- accessibility indicator for a node with x!, y! coordinates with a node x, y coordinates.

The accessibility of territory with number i for territory with number j is determined by the expression D_{ij}.

$$D_{ij} = \iint\limits_{Д_i} \overline{Д}(x^!, y^!)\, q(x^!, y^!)\, dx^!\, dy^! \tag{9}$$

Substituting expression (8) into (9) we have

$$D_{ij} = \iint\limits_{Д_i} \iint\limits_{Дj} P(x, y, x^!, y^!)\, q(x, y)\, q(x^!, y^!)\, dx\, dy\, dx^!\, dy^! \tag{10}$$

$$\left.\begin{aligned} &\text{Where } \iint\limits_{Д_i} q(x^!, y^!)\, dx^!\, dy^! = 1 \\ &\iint\limits_{Дj} q(x, y)\, dx\, dy = 1 \end{aligned}\right\} \tag{11}$$

The value of D_{ij} can also be determined as follows

$$Д_{ij} = \iint\limits_{Дj} Д(x^!, y^!)\, q(x^!, y^!)\, dx^!\, dy^! \tag{12}$$

Substituting expression (9) into (12) we have

$$Dij = \iint\limits_{Дj} \iint\limits_{Д_i} P(x^!, y^!, x, y)\, q(x, y)\, q(x^!, y^!)\, dx\, dy\, dx^!\, dy^! \tag{13}$$

From (9) and (12) we have the equality

$$\iint\limits_{Д_i} \overline{Д}(x^!, y^!)\, q(x^!, y^!)\, dx^!\, dy^! = \iint\limits_{Дj} Д(x^!, y^!)\, q(x^!, y^!)\, dx^!\, dy^! \tag{14}$$

The mutual accessibility of territory D^{ij} with numbers i and j has the following expression:

$$D^{ij} = \frac{Dij + Dji}{2} \tag{15}$$

IRA of the territory has a form

$$Д_{ii} = \iint_{Д_i} \iint_{Д_i} P(x, y, x^{!,} y^{!})\, q(x,y)\, q(x^{!,} y^{!})\, dx\, dy\, dx^{!}\, dy^{!} \tag{16}$$

where $P(x, y, x^{!,} y^{!})$ - accessibility indicator from a node with x, y coordinates, to a node with $x^{!,} y^{!}$ coordinates. q (x,y) – a node weight with coordinates x, y; $q(x^{!,} y^{!})$ - a node weight with coordinates $x^{!,} y^{!}$.

The transition to a higher level of accessibility according to the hierarchical model was described earlier in simplified expressions. In this case, we note concepts such as “node” and “territory”.

IRA (D) based on the private components of the accessibility, Di is calculated by the following functions [1]:

$$Д = \sum_{i=1}^{l} q_i Д_i \tag{17}$$

Where qi – weight of this particular accessibility component; $Д_i$ - private accessibility.

As a weight q we can use following expression [1]:

$$q=P_0 N + (1-P_0)\rho \tag{18}$$

where N – population; P0- weight of population ; ρ - GDP.

Weight of population can be defined as follows [2]:

$$P_0 = \frac{\prod_{i=q}^{k} V_i}{\sum_{g=1}^{k} \prod_{i=q}^{k} V_i} = \frac{V_1 V_2 V_3 V_4}{V_1 V_2 V_3 V_4 + V_2 V_3 V_4 + V_3 V_4 + V_4} \tag{19}$$

Where, V- vector of prioritization.

According to the procedure for specifying the vector V, we should first set the priority series J, then the priority vector, and based on the vectors J and V, the weight vector P_0. Priority series J is set by the number of inhabitants of points on the following scale:

- More than 2500000, (J1 = 1), (V1 = 5);
- From 2,000,000 to 2,500,000, (J2 = 2), (V2 = 4);
- From 1,500,000 to 2,000,000, (J3 = 3), (V3 = 3);
- From 1,000,000 to 1,500,000, (J4 = 4), (V4 = 2);
- Less than 1,000,000, (J5 = 5), (V5 = 1).

Here, priority range J=(1,2,3,4,5) and vector priority $V=(V_1,V_2,V_3,V_{4,}V_5)=(5,4,3,2,1)$.

As indicators of accessibility, depending on the goals and nature of the task, we use the travel time [1]:

$$P(t) = \frac{L}{V_a}\left(1+\frac{\sigma_v^{\ 2}}{V_a^{\ 2}}\right);\text{(hours)} \tag{20}$$

where,

V_a – average travel speed; σ_v – standard deviation; L – distance between nodes; t – travel time.

Average travel speed V_a is defined depending on traffic flow [3]:

$$V_{flow} = V - (A - B\, P_{pas})\, N + C\, P_{pas}\ \text{, km/h;} \tag{21}$$

where V = 60 km/h, A = 0.028, B = 0.0002, C = 0.29 for two lane roads; V = 77 km/h, A = 0.024, B = 0.00016, C=0.28 for four lane roads; A = km/vehicle, B = км/авт, C = км/авт; P_{pas} – share of passenger cars in traffic flow, %, N-traffic volume, veh/h.

Standard deviation σ_v depending on road condition defines according to:

$$\sigma_v = C_v\, K_\sigma\, V_{cp} \tag{22}$$

where: C_v – coefficient of variation, depending on longitudinal slope i; K_σ - coefficient, which takes into account influence of road parameters to σ_v. Coefficients are defined as follows::

$$K_\sigma = K_R\, K_S\, K_\Gamma\, K_P \tag{23}$$

Where indexes R, S, Γ, P – curve radius, sight distance, bridge parameters, length of straight section:

$$\left.\begin{array}{l} KR = 1 - 0.58\ e\text{-}0.008R \\ KS = 1 - 0.44\ e\text{-}0.0084S \\ K\Gamma = 1 - 0.29\ e\text{-}0.98\ (\Gamma\text{-}6) \\ Kp=1\text{-}0.0013P\ (P+2) \end{array}\right\} \tag{24}$$

To test the methodology, we determine the integrated road accessibility of the Republic of Uzbekistan. The territory of the republic is 447.4 thousand km^2, and the population is 33.4 million people. The capital of the Republic is the city of Tashkent with population 2114.0 thousand people. Tashkent is the leading industrial center of the Republic and has a high status in the Central Asian region. The city is located 473 m above sea level. To assess the quality of the road network of the Republic of Uzbekistan, it is very important to determine the IRA from Tashkent to any point in the republic. The total length of the road network of the Republic of Uzbekistan is 184,000 km, of which 42,695 km are public roads. The density of the network of public roads is 95.2 km / 1000 km^2.

To determine the IRA, we chose the capital of the Republic of Karakalpakstan and 12 the capital of the regions of the republic, with a total number population from 8000 to 220,000. We calculate the weight of each point using formula 3. We find the population weight by formula 4. We determine the distance to the nodes based on the options for the shortest routes. And for each route, you need to determine the average speed according to the formulas 6 and 7. Using formulas 8, 9, 10 and 5, we determine the IRA from Tashkent to nodes. The calculation results are shown in the following table:

Table 1

Nodes	N, thous. people	P_0	Shortest Routes	L,km	$V_a$km/h	Altitude, m	i, ‰	Cv	K_σ	σ_v	IRA, hours
Nukus	1875,4	0,039	M39, M34, A373, M39, M37, A380	1255	78,4	78	-0,2	0,190	0,94	14,0	16,52
Andijan	3077,2	0,784	A373a, A373	350	82,7	502	0,2	0,190	0,96	15,1	4,37
Bukhara	1900,0	0,039	M39, M34, A373, M39, M37	600	78,5	225	-0,4	0,190	0,96	14,3	7,90
Djizak	1358,2	0,013	M39, M34, A373, M39, A376	200	74,7	378	-0,3	0,190	0,96	13,6	2,77
Karshi	3225,8	0,784	M39, M34, A373, M39, A378	430	76,9	386	-0,1	0,190	0,94	13,7	5,77
Navoiy	982,6	0,006	M39, M34, A373, M39, M37	480	78,8	365	-0,2	0,190	0,96	14,4	6,29
Namangan	2763,1	0,784	A373a, A373, 4P112	290	83,0	476	0,1	0,190	0,96	15,1	3,61
Samarkand	3813,6	0,784	M39, M34, A373, M39	300	77,0	785	1,2	0,191	0,94	13,8	4,02
Termez	2580,6	0,784	M39, M34, A373, M39	680	75,1	306	-0,2	0,190	0,94	13,4	9,34
Gulistan	833,0	0,006	M39, M34	115	73,5	273	-1,5	0,188	0,95	13,2	1,62
Nurafshan	2907,0	0,784	4P2	30	84,0	480	1,3	0,191	0,94	15,1	0,37
Fergana	3695,5	0,784	A373a, A373, 4P112	315	85,1	580	0,4	0,190	0,94	15,2	3,82
Urgench	1841,0	0,039	M39, M34, A373, M39, M37, A380, 4P161	1000	77,9	103	-0,3	0,190	0,94	13,9	13,25
Tashkent	2522,8	0,784	-	-	-	440	-	-	-	-	-

Based on the results of table 1, a graph is drawn and boundaries of the IRA levels are identified (Figure 1).

Figure 1: IRA Boundaries.

As per the figure, the IRA level is divided into the following zones:

- IRA up to 3,5 hours;
- IRA from 3,5 to 4,0 hour, (normative zone);
- IRA from 4,0 to 6,0 hour;
- IRA from 6,0 to 9,0 hour;
- IRA more than 9,0 hour.

Figure 2 shows a map of the integrated road accessibility of the Republic of Uzbekistan, which was compiled according to the calculation results, which shows the level of IRA and each level determines the quality of the road network and traffic conditions. Based on the IRA zoning map, measures are being developed to improve the quality of the road network and the traffic conditions, as well as the transport security of the Republic of Uzbekistan.

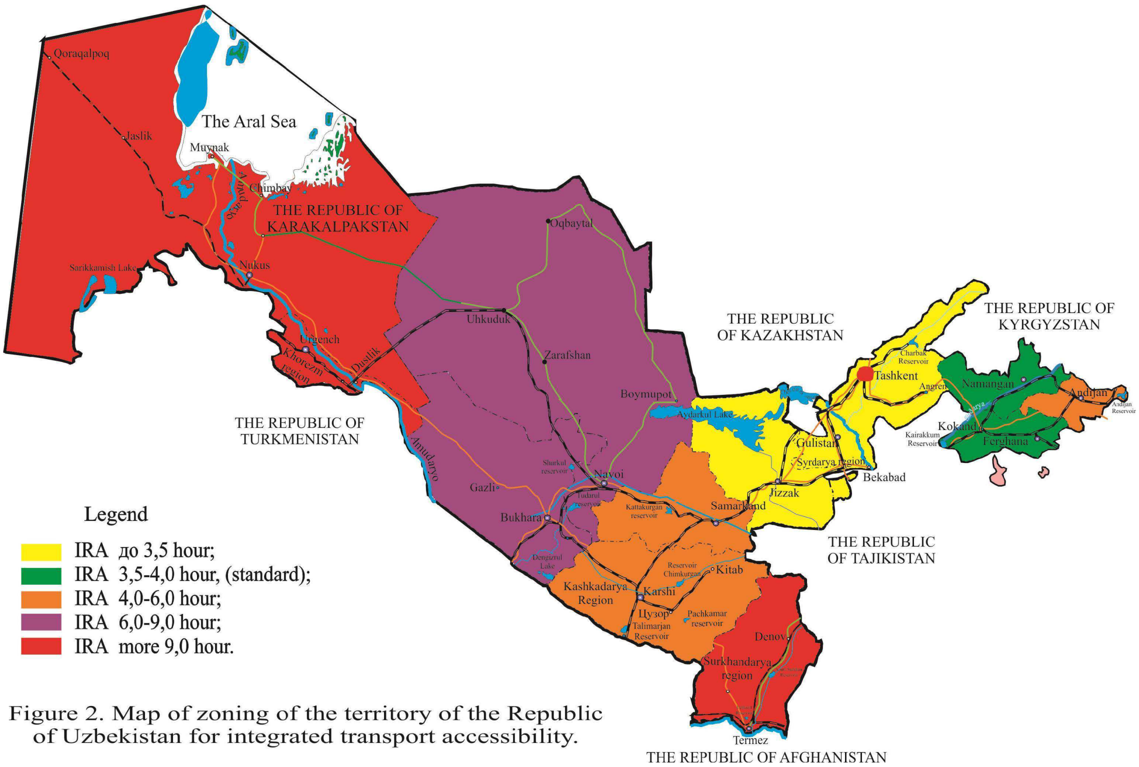

Figure 2. Map of zoning of the territory of the Republic of Uzbekistan for integrated transport accessibility.

Figure

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Aslidin Khoshvaktovich Urokov graduated from the Tashkent Institute of motor roads with honors in 1993 in the specialty "construction of highways and airfields". He defended his Ph.D dissertation in 2010 Year, was awarded the title of associate professor in 2012 year. From 2013 to the present day, hi is head of "highway construction and maintenance" department.

In 2003 and 2005, he received a qualification in the automated design system CREDO at the Moscow Institute of Highways (State Technical University)of the Russian Federation. 2014 year was in Japan on a grant from the Japan International Cooperation Organization JICA. In 2016, he has been trained at the Portuguese Polytechnic Institute of Branco in Costa Rica. He was in the internship for the construction of the road on the basis of the SABIT program in the US in 2018.

Aslidin Khoshvaktovich carried out scientific research for many years, Urokov published 60 scientific articles, 21 highway normative documents, 33 different scientific-methodical works and 3 monographs, 6 manuals, 5 textbooks. He led A-3-54 state grant on the theme "selection of parameters and description of the hanging part of a car for smooth movement on the highways of Uzbekistan" and HIGHVEC: 544061-TEMPUS-1-2013-1-UK-TEMPUS-JPCR participated in the TEMPUS international project entitled "development of new master's programs in highway construction and automotive engineering.